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Pathogenic Micro-organisms
in Water
by
P. F. Frankland.

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ON THE PRESENCE AND VITALITY OF PATHOGENIC MICRO-ORGANISMS IN WATER.

By PERCY F. FRANKLAND, Ph.D., B.Sc., F.C.S., F.I.C.

THE improvement in the methods of bacteriological research which has been brought about within the past ten years has opened up a vast field of experimental inquiry into the behaviour of micro-organisms in potable water. This branch of bacteriological investigation is peculiarly attractive in consequence of the irresistible evidence which has been collected during the latter half of the present century, that several at least of those diseases which are known as *zymotic*, or, in other words, brought about by the agency of living organisms, are frequently, if not most generally, propagated through the medium of drinking-water. Amid the feverish activity with which the study of micro-organisms in general is being now prosecuted, unfortunately, more especially in foreign countries, owing to the hampering legislation with which this study is fettered at home, it is not surprising that this particular branch—the bacteriology of water—should also be receiving its share of attention.

The inauguration of this investigation not unnaturally took the form of determining the relative abundance and nature of the micro-organisms present in drinking-water obtained from various sources and under various conditions. The more sanguine investigators were doubtless of opinion that these researches into the nature of the micro-organisms present in natural waters would readily lead to the discovery of forms possessing pathogenic properties in some waters, and that upon the absence or presence of such disease-producing organisms it would be possible to found an opinion as to the fitness or unfitness of water for dietetic purposes. There are many persons who still regard such a discovery as the ultimate scope of the bacteriological examination of water; but a little reflection will at once show how small is the interest or value attaching to such an investigation. Thus, to take a concrete example, let us suppose that a well supplying drinking-water is situated in suspicious proximity to a cesspool, and it is desired to ascertain whether there is any danger of noxious matters passing from the cesspool to the well. It is obvious that in such a case it would be quite worthless to endeavour to discover the organism which, rightly or wrongly, is believed to be capable of producing typhoid fever in the water of the well unless the excreta of a typhoid patient had been recently discharged into the cesspool. How many of the most obviously contaminated wells could be condemned, if it was first necessary to prove the presence of a pathogenic organism in their waters? On this account I have myself never been of opinion that the discovery of pathogenic organisms in water, even if such discovery could be made with great facility, possesses any considerable sanitary importance; but, on the other hand, I am very strongly of opinion that the demonstration of the passage of *any* living organisms, pathogenic or harmless, from a centre of contamination into a source of drinking-water is a matter of vital consequence. Thus the greatest interest must attach to an inquiry into the power which micro-organisms *of any kind* possess of finding their way through obstacles, whether natural or artificial, which are interposed between centres of contamination and sources of water-supply.

The first sanitary problem in the bacteriology of water which suggested itself was, therefore, to inquire into the efficiency or inefficiency of filtering media, natural or artificial, in retaining micro-organisms of any kind. Much work has been already accomplished in this direction,* the general result of which has been to display the hollowness of the much advertised professions which many filtering patents and nostrums make of entirely removing living organisms from water; whilst, on the other hand, these investigations have shown that many processes of filtration, which formerly were regarded as practically valueless in removing these minute forms of organic life, are really possessed of very considerable efficiency in this respect. Again, they have shown that waters which have undergone exhaustive natural filtration through porous strata are almost perfectly free from micro-organisms, and have thus confirmed the high reputation which such waters enjoy for drinking purposes. It is now only a matter of time for practical men, such as water-engineers, to appreciate the value of the bacteriological examination of water as a guide in the construction and working of filter beds and other purifying plant.

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* 'The Removal of Micro-organisms from Water.' P. F. Frankland. *Proceedings Royal Society*, No. 238. 1885.

'New Aspects of Filtration and other Methods of Water Treatment.' *Ibid. Journal Society of Chemical Industry*, Dec. 29, 1885.

'Water Purification: its Biological and Chemical Basis.' *Ibid. Proceedings Institute of Civil Engineers*, April 1886.

'Filtration of Water for Town Supply.' *Ibid. Transactions Sanitary Institute of Great Britain*, 1886.

These points have been fully demonstrated in the systematic bacteriological examinations which I have now made of the Metropolitan Water Supply for a period of upwards of two years. In these investigations samples of unfiltered river water, and of the same water after purification and as delivered to the consumer by the water companies, are simultaneously submitted to examination. These examinations reveal the highly important fact that, whilst the number of micro-organisms present in the unfiltered water is usually very great, amounting occasionally to about one hundred thousand in a cubic centimètre, or, what is more easily realisable, to five thousand in a single drop of average size, the same water, after purification by storage and filtration, contains a comparatively very small number, frequently not exceeding one hundred in the cubic centimètre. This great contrast between the number of organisms present in the unfiltered and filtered waters respectively clearly shows that in the treatment to which the water is subjected a most important

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'Ueber die Beschaffenheit des Berliner Leitungswasser.' Dr. G. Wolffhügel. *Arbeiten aus dem Kaiserlichen Gesundheitsamte.* Berlin. 1886.

'Ueber Wasserfiltration.' Dr. Plagge. *Chemisch-technischer Central-Anzeiger*, 1886.

reduction in the number of micro-organisms is effected. In illustration of this, I may quote from my monthly reports to the Local Government Board during the past year 1886, which show that the average reduction in the micro-organisms present in the unfiltered waters of the rivers Thames and Lea effected before delivery to the consumer amounted to 97·6 in the case of the Thames, and 96·5 in the case of the Lea, thus :—

1886.	Thames.	Lea (East London Company).
January	95.6 per cent.	99·4 per cent.
February	98·6 ,,	98·8 ,,
March	95·3 ,,	94·1 ,,
April	99·1 ,,	96·3 ,,
May	98·8 ,,	95·2 ,,
June	98·9 ,,	90·5 ,,
July	95·6 ,,	97·5 ,,
August	94·0 ,,	94·3 ,,
September	99·4 ,,	95·5 ,,
October	99·4 ,,	98·5 ,,
November	99·8 ,,	98·0 ,,
December	98·3 ,,	99·8 ,,

In experiments of this kind it is wholly immaterial whether the micro-organisms present in the water under examination are hurtful or harmless, for there is not a tittle of evidence to show that the one kind of microbe would behave any differently under the circumstances from the other; indeed, there can be no doubt whatever that a filter capable of removing non-pathogenic organisms will also be equally efficient in the removal of pathogenic forms.

From the above results it will be seen that, although the process of filtration as practised by water companies does not afford an absolute guarantee against the transmission of organisms, yet the efficiency indicated is so encouraging that, when scientific assistance is brought to bear upon the rule-of-thumb methods in vogue amongst water engineers, there is every hope that still greater efficiency will be attained, and at any rate the results must stimulate those who have the management of waterworks in their hands not to relax their endeavour to secure the most careful and uniform filtration possible.

But whilst the problems connected with the bacteriology of water may be solved without any reference to the nature of the micro-organisms, as in the case of the filtration experiments referred to above, there are other questions which can only be answered by experimenting with organisms known to possess particular pathogenic properties. The first question of this nature which presents itself is as to how far water is capable of acting as a carrier for pathogenic micro-organisms. Now the possibility of finding such pathogenic organisms in natural waters which have undergone contamination is excessively remote, for in all cases in which pathogenic forms have gained access to water they will have been accompanied by enormously larger quantities of harmless forms, and thus the search for the few pathogenic in the presence of the immense excess of non-pathogenic forms much resembles the search for a pin in a hay-stack. Owing to this difficulty it is necessary to approach the question *synthetically*, so to speak. This may be done artificially by introducing known pathogenic forms into waters of different kinds, and then observing what becomes of the organisms thus introduced, whether they increase and multiply, or decline and perish. This inquiry has already been commenced, and a number of results obtained. The principal organisms which have been experimented with in this manner are Koch's comma spirillum, Finkler-Prior's comma spirillum, the bacillus anthracis, Gaffky's typhoid bacillus, the staphylococcus aureus, the bacillus pyocyaneus, and the micrococcus tetragenus.

Of the above organisms, those with which I have myself experimented are Koch's and Finkler's spirilla, as well as the bacillus pyocyaneus.* These three microbes in themselves presented very marked differences: thus the bacillus pyocyaneus, an organism which produces the greenish blue colouring matter frequently present in abscesses, was found to be capable of flourishing in all kinds of water, in sewage, in filtered Thames, in deep well water, and even in distilled water. Koch's comma spirillum, on the other hand, was found to be capable of enormous multiplication in sewage, whilst in potable water—filtered Thames or deep well water—little or no multiplication of the organism took place, and in the course of a few weeks it had generally either disappeared or had become very much reduced in number. Finkler's spirillum, lastly, which resembles Koch's so closely in microscopic appearance and in many other respects that it was by its discoverers erroneously supposed to be identical with Koch's comma spirillum of Asiatic cholera, could not be preserved in water of any kind, neither in sewage nor in filtered Thames water, nor in deep well water. When the Finkler spirilla were introduced into these media, in no case could their presence be demonstrated after the first day. These differences alone point to the great importance of investigating the behaviour of every individual kind of pathogenic organism, and of the danger of generalising on the subject from observations made on a limited number of forms. A very curious phenomenon was frequently observed in the case of the comma spirillum and the bacillus pyocyaneus, viz., that when these organisms were introduced into the purer kinds of water, at first their numbers were very greatly reduced, sometimes to such an extent that not a single organism could be demonstrated even in a whole cubic centimètre of water, whilst subsequently more or less multiplication took place. This would appear to be due to a certain length of time being necessary for these micro-organisms to become accustomed to the new medium.

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* 'On the Multiplication of Micro-organisms.' *Proceedings Royal Society*, No. 245, 1886.

'Ueber das Verhalten verschiedener Bacterienarten im Trinkwasser.' By Meade Bolton. *Zeitschrift für Hygiene*, erster Band, erstes Heft. Leipzig: 1886.

In experiments of this kind, undertaken with the bacillus anthracis, the investigation is complicated by the circumstance that this organism, as is well known, appears in two very distinct forms—viz., as bacilli and as spores. Now the bacilli, or fully developed organisms, are far less capable of resisting hostile influences than the spores; thus the bacilli succumb to heat, desiccation, and disinfectants long before the spores are affected at all. It would be anticipated, therefore, that very different results should be obtained with anthrax in water, according as the bacilli or the spores of this organism were introduced into the water. Now actual experiments have entirely borne out these expectations, for it has been shown that when the bacilli of anthrax are introduced into potable water they generally perish in the course of a day or two, whilst the spores when similarly introduced retain their vitality for many months. But it must be remembered that almost invariably the bacilli of anthrax are accompanied by spores; in fact, the only way of obtaining with certainty the bacilli absolutely free from spores is by taking the organs or blood of an animal recently dead of anthrax, since, whenever a medium containing the organism is exposed to the air at the ordinary temperature, spore-formation is liable to take place. It is obvious, therefore, that only those experiments on the vitality of the anthrax-organism in water *in which the spores have been employed can have any claim to being of sanitary importance*, and any conclusions based upon the behaviour of *sporeless* growths of anthrax bacilli in water are not only valueless, but misleading in the extreme. It is of the greatest importance that this point should be clearly understood, as there have been endeavours made to attract undue attention to the transient existence of *sporeless* anthrax bacilli in potable water; and, should these facts be misinterpreted, there is every probability that they would tend to foster a most dangerous and reprehensible laxness in preserving the purity of water supplies. The experiments with Gaffky's typhoid bacillus show that, although this organism does not appear to be capable of actual multiplication in ordinary potable water, yet its vitality is preserved for at least ten or fourteen days even in distilled water. Of the experiments which have been made with other pathogenic microbes—viz., staphylococcus aureus and micrococcus tetragenus—it may be briefly stated that they appear neither to multiply in potable water nor to be capable of any prolonged vitality in that medium; but it must be remembered that neither of these organisms is known to form spores, and hence their limited powers of resistance to unfavourable conditions is in no way surprising.

From the above sketch of the present state of our knowledge concerning the vitality of pathogenic micro-organisms in water, it is evident that there is still much in connection with this subject which requires investigation. But the following facts are most conclusively proved :—

1. That the pathogenic organisms do not present any special uniformity in their behaviour in potable water, and that, therefore, it is highly misleading to apply the results which have been obtained with one organism to the case of another organism.

2. That, although most of the pathogenic forms which have hitherto been experimented with do not appear to be capable of extensive multiplication in potable water, yet many of them are able to preserve their vitality in this medium for a considerable time—many days or weeks—and those which, like the bacillus anthracis, form spores retain their vitality for practically an indefinite period of time.

These two points, which are so forcibly brought out by the experiments in question, are not without an important bearing upon sanitary science; for, whilst they show that pathogenic organisms which gain access to potable water may occasionally lose their vitality before any mischief is done, yet that their spontaneous destruction in this manner can in no way be relied on. Thus the results serve on the one hand to explain many cases in which waters known to be contaminated with typhoidal matters and the like have failed to communicate disease, and, on the other hand, they prove most conclusively how such diseases are communicable by water. In short, the most recent researches in the bacteriology of water tend to show that, whilst the chances of some diseases being communicated through this medium are less than has often been represented, yet that no absolute reliance can be placed on filtration nor on the spontaneous destruction of pathogenic micro-organisms in potable water. Under these circumstances it is fortunate that the private water-consumer may obtain practically absolute security against pathogenic microbes in water by the simple process of boiling, which is a more effectual, a less costly, and more readily applicable germicide than any of the numerous filters which the ingenuity or caprice of patentees has devised.

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